Understory flora and community physiognomy of planted forests in the degraded purple soil ecosystem, South China

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Abstract: The flora and community physiognomy of degraded plantation ecosystems on purple soil were investigated in Ninghua County of Fujian Province, China to understand the relationship between plant diversity and ecosystem processes.. Four different restoration communities (labeled as ecological restoration treatment I, II, III and IV) were selected by space-time replacement method according to the erosion intensity in degraded purple soil ecosystem. The results showed that there were totally 86 plant species belonging to 78 genera and 43 families in the degraded purple soil ecosystem. Of the 15 types of distribution area in spermatophyte genus, 12 types were found in the purple soil ecosystem. Along restoration gradient from low to high, plant growth type and life form spectra became abundant more and more, and the spermatophyte genera for each distribution area type and genera numbers for different foliage characters increased as well. It is concluded that the plant flora and physiognomy in ecological restoration process become more complex and diverse, indicating that the forest ecosystem on purple soil tends to be more stable.

Keywords: Purple soil; Flora; Community physiognomy; Biodiversity; Ecosystem processes
CLC number: S718.55 **Document code**: A **Article ID**: 1007-662X(2005)02-0109-04

Introduction

Concerns over the unprecedented loss of biodiversity have motivated ecologists to conduct considerable research (Loreau *et al.* 2001; Lyons *et al.* 2001), describing the relationship between biodiversity and ecosystem function, and detecting the mechanisms by which diversity impacts ecosystem functioning (Loreau 2000; Zak *et al.* 2003). A major future challenge in ecology is how to determine the biodiversity dynamics, ecosystem processes, and interaction of abiotic factors (Loreau *et al.* 2001). Although flora and physiognomy are the basis of biodiversity research, little has been known about the relationship between flora and physiognomy and restoration process of degraded ecosystem. Purple soil is one kind of important soil types for dry farming in southern China (Yang 1992), which is fertile and easily eroded (Yang and Li 1993; Zheng and Shen 1998). However, only few of researches reported the restoration process of degraded purple soil ecosystem (Yu 2004; Dai *et al.* 1995; Zheng and Shen 1998). Our study is to document dynamics of flora and physiognomy along restoration gradient. The information may be useful to supply groundwork and knowledge for biodiversity protection and restoration ecology.

Study area and methods

Study area

The study was conducted in Ninghua County (116°22'–117°02' E, 25°58'–26°40' N), Fujian Province, China. This region belongs to a subtropical monsoonal climate with a mean annual temperature of 17.8°C.The mean annual precipitation is 1 769.3 mm, mainly from February to June. The growing season is long, and the annual frost-free period is about 255 days. The soil is classified as purple soils and 44% of purple area was intensely eroded (Yu *et al.* 2004).

Methods

Four plantation communities represented different restoration stages were selected by space-time replacement method, which were separately named as treatments I, II, III and IV, to study the ecological restoration processes of purple soil ecosystems. Treatments I–IV separately represented the restoration gradient of erosion intensity from intense to tiny. In each community, three 20 m×20 m plots were established along altitude gradient. Each plot was then divided into sixteen subplots (5 m×5 m) to survey species composition for analyzing flora and physiognomy. Some basic properties of plots are described in Table 1.

Results and analysis

Floristic composition

There were 86 plant species belonging to 78 genera and 43 families in the degraded purple soil ecosystems. From treatment I to treatment IV, numbers of families, genera and species took on an increasing tendency. Compared with treatment I, increments of 4 families, 5 genera, and 5 species were found in treatment II, and the corresponding increments for treatment III were 14 families, 28 genera, and 32 species. Increases of floristic composition in treatment IV were most, up to 30 families, 54 genera and 57 species. Along restoration gradient, angiosperms dominated in floristic composition of the degraded ecosystem. For example, 6, 9, 15, and 29 families of dicotyledons separately appeared along the 4 restoration gradients. Number of families,

Foundation item: This project was supported by Innovation Research Project of Chinese Academy of Sciences (KZCX3-SW-418)
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Received date: 2004-12-27
Responsible editor: Song Funan

genera, and species in understory of each community followed the order: Gymnosperms < Ferns < Monocotyledons < Dicotyledons (Table 2).

Table 1. General situation of different restoration communities in degraded purple soil ecosystem in Ninghua County, Fujian Province, China

Treatments	Slope degree (°)	Slope direction	Bulk density (g·cm^{-3})	Organic matter (g·kg^{-1})	Erosion intensity	Understory coverage (%)
I	7.0	South	1.57	0.21	Intense	10
II	6.5	South	1.50	0.45	Medium	20
III	9.0	South	1.31	1.24	Light	90
IV	28.0	South	1.29	1.69	Tiny	85

Note: Treatments I–IV separately represented four different restoration communities along the restoration gradient of erosion intensity from intense to tiny. Same explanation for Table 2–6.

Table 2. Floristic composition of understory in different restoration communities in degraded purple soil ecosystem

Composition	Restoration communities																				Total
	I					II					III					IV					
	A	B	C	D	Sum	A	B	C	D	Sum	A	B	C	D	Sum	A	B	C	D	Sum	
Families	1	0	6	2	9	2	0	9	2	13	4	1	15	3	23	7	0	29	3	39	43
Genera	1	0	8	2	11	2	0	12	2	16	4	1	28	6	39	8	0	50	7	65	78
Species	1	0	8	2	11	2	0	12	2	16	4	1	32	6	43	8	0	53	7	68	86

Note: A--Ferns; B--Gymnosperms; C--Dicotyledons; D--Monocotyledons

Generic areal-types of spermatophyte

According to the types of distribution areas (Wu 1991), the generic areal-types of spermatophyte along restoration gradient were analyzed. Of the 15 types of distribution area, 12 types were found in the purple soil ecosystems, and tropical types accounted for 55.07%. So genera of plant were multiple and complex and geographical composition was characterized by tropical flora in the purple soil ecosystem. Pan-tropical type was dominant in generic areal-types of spermatophyte and there were no types of central Asia, endemic to China and Mediterranean, West Asia to Central Asia in different restoration communities. Generic numbers in every appeared distribution area type were markedly increasing along restoration gradients, especially total generic numbers (Table 3). Based on the results mentioned above, it is obvious that plant diversity gradually increased in the purple soil ecosystem during the communities' restoration.

Table 3. Generic areal-types of spermatophyte in different restoration communities

Distribution area types	Restoration communities							
	I		II		III		IV	
	Genera	Percent (%)	Genera	Percent (%)	Genera	Percent (%)	Genera	Percent (%)
Cosmopolitan	1	10.00	2	14.29	3	8.57	6	10.53
Pan-tropical	4	40.00	4	28.57	14	40.00	15	26.32
Trop. Asia & Trop. America Disjuncted	0	0.00	0	0.00	0	0.00	1	1.75
Old-World tropics	0	0.00	0	0.00	0	0.00	3	5.26
Trop. Asia & Trop. Australia	1	10.00	1	7.14	2	5.71	2	3.51
Trop. Asia to Trop. Africa	1	10.00	1	7.14	1	2.86	3	5.26
Tropical Asia	1	10.00	1	7.14	2	5.71	6	10.53
North Temperate	0	0.00	2	14.29	5	14.29	9	15.79
East Asia & North America Disjuncted	1	10.00	2	14.29	6	17.14	7	12.28
Old-World Temperate	0	0.00	0	0.00	0	0.00	1	1.75
Temperate Asia	0	0.00	0	0.00	0	0.00	1	1.75
Mediterranean, West Asia to Central Asia	0	0.00	0	0.00	0	0.00	0	0.00
Central Asia	0	0.00	0	0.00	0	0.00	0	0.00
East Asia	1	10.00	1	7.14	2	5.71	3	5.26
Endemic to China	0	0.00	0	0.00	0	0.00	0	0.00
Total of Tropics	7	70.00	7	50.00	19	54.29	30	52.63
Total	10	100.00	14	100.00	35	100.00	57	100.0

Community physiognomy

Growth type: Plant growth type is one of the most important indices for physiognomy and vertical structure of community (Xie *et al.* 1994). Evergreen shrub was dominant in various growth types in the degraded purple soil ecosystem, accounting for 27.91% of the total genera number. This was in accordance with the results of restoration communities of *Pinus massoniana* plantation in Bashili River watershed, Fujian Province (Wang 2002). With the exception of evergreen shrub, there were separately 14 and 12 genera for perennial grasses and evergreen arbor, while the proportion of deciduous liane and grassy liane was the least (2.33%). There were only 6 genera of evergreen shrubs, 3 genera of perennial herbs, 1 genus of evergreen liane, and 1 genus of fern in the community of treatment I, with a monotonous growth type. Genera numbers of arbor, shrub and fern remarkably increased in communities of treatment II, III and IV compared with those in treatment I (Table 4).

Table 4. Growth types of understory in different restoration communities in degraded purple soil ecosystem

Treatments	Number of genera									
	Indeciduous arbor	Deciduous arbor	Indeciduous shrub	Deciduous shrub	Indeciduous liane	Deciduous liane	Herbaceous liane	Perennial herb	Ephemeretum	Fern
I	0	0	6	0	1	0	0	3	0	1
II	1	1	7	1	1	0	0	3	0	2
III	5	5	13	3	2	2	0	6	3	4
IV	7	3	21	5	5	1	2	13	3	8
Total	12	7	24	7	5	2	2	14	4	9
(%)	13.95	8.14	27.91	8.14	5.81	2.33	2.33	16.28	4.65	10.47

Life-form spectrum: Spectra of life form provides a comprehensive system for the classification of plant life form based on their long-term adaptations for the unfavorable seasons (winter cold or summer drought) (Chen *et al.* 2002). Raunkiaer (1934) classified plants as phanerophyte, chamaephytes, hemicryptophytes, crytophytes, and therophytes according to the position and protection pattern of dormant bud. In this investigation, Phanerophyte plants were sorted into megaphanerophyte, macrophanerophyte, mesophanerophyte, microphanerophyte, and nanophanerophyte plants. Combined with Raunkiaer's life form classification system, life form spectra were constructed for understory in different restoration communities (Table 5). Life form spectra became multiple from treatment I to treatment IV. Microphanerophyte species were most popular in every community, followed by crytophytes and mesophanerophyte species, which reflected the warm and wet subtropical climate conditions. Species numbers of microphanerophyte, crytophytes and mesophanerophyte along restoration gradient increased significantly, while their proportions of plant life form decreased, which may be the consequence of biodiversity restoration. For example, species numbers of microphanerophyte plants were 5, 7, 16, and 24 for treatment I, II, III and IV, respectively, but their corresponding percentages of total species were 45.45, 43.75, 37.21, and 35.29, respectively.

Table 5. Life-form spectrum of understory in different restoration communities in degraded purple soil ecosystem

Treatments		Megaphanerophyte	Macrophanerophyte	Mesophanerophyte	Microphanerophyte	Nanophanerophyte	Chamaephytes	Hemicryptophytes	Crytophytes	Therophytes
I	Genera	0	0	1	5	1	1	0	3	0
	Percent (%)	0.00	0.00	9.09	45.45	9.09	9.09	0.00	27.27	0.00
II	Genera	1	0	2	7	1	1	0	4	0
	Percent (%)	6.25	0.00	12.50	43.75	6.25	6.25	0.00	25.00	0.00
III	Genera	2	3	5	16	4	1	2	7	3
	Percent (%)	4.65	6.98	11.63	37.21	9.30	2.33	4.65	16.28	6.98
IV	Genera	0	3	9	24	6	2	8	13	3
	Percent (%)	0.00	4.41	13.24	35.29	8.82	2.94	11.76	19.12	4.41

Foliage characteristics: In the purple soil ecosystem, small-sized leaf plant of understory was dominant, accounting for 53.49% of total genera, followed by middle-sized leaf plant, accounting for 31.40%, and there were no huge-sized leaf and aphylly plant (Table 6). This indicated that the small-sized leaf plant can reduce transpiration in severe environment.

Table 6. Foliage characteristics of understory in different restoration communities in degraded purple soil ecosystem

Treatments		Leaf size							Leaf shape		Leaf quality				Costa	
		S1	S2	S3	S4	S5	S6	S7	Sh1	Sh2	Q1	Q2	Q3	Q4	C1	C2
I	Genera	0	0	1	6	4	0	0	8	3	0	4	6	1	9	2
	Percent (%)	0.00	0.00	9.09	54.55	36.36	0.00	0.00	72.73	27.27	0.00	36.36	54.55	9.09	81.82	18.18
II	Genera	0	0	1	9	5	1	0	11	5	0	7	8	1	9	7
	Percent (%)	0.00	0.00	6.25	56.25	31.25	6.25	0.00	68.75	31.25	0.00	43.75	50.00	6.25	56.25	43.75
III	Genera	0	2	4	23	13	1	0	25	18	2	25	13	3	29	14
	Percent (%)	0.00	4.65	9.30	53.49	30.23	2.33	0.00	58.14	41.86	4.65	58.14	30.23	6.98	67.44	32.56
IV	Genera	0	0	5	37	22	4	0	47	21	5	39	22	2	37	31
	Percent (%)	0.00	0.00	7.35	54.41	32.35	5.88	0.00	69.12	30.88	7.35	57.35	32.35	2.94	54.41	45.59
Total	Genera	0	2	7	46	27	4	0	58	28	6	49	28	3	49	37
	Percent (%)	0.00	2.33	8.14	53.49	31.40	4.65	0.00	67.44	32.56	6.98	56.98	32.56	3.49	56.98	43.02

Note: S1-Aphylly; S2-Bulbill leaf; S3-Micro-sized leaf; S4-Small-sized leaf; S5-Middle-sized leaf; S6-Macro-sized leaf; S7-Huge-sized leaf; Sh1- Simple leaf; Sh2- Compound leaf; Q1- Thin leaf; Q2- Grassy leaf; Q3- Leathery leaf; Q4- Thickly leathery leaf; C1- Entire leaf; C2- Incomplete leaf.

The main leaf shape of plant was simple leaf, accounting for 67.44% of total genera. Grassy leaf and leathery leaf were dominant for leaf quality, making up 56.98% and 32.65% of the total genera number, respectively. As far as leaf costa concerned, genera number of entire leaf was a little more than that of incomplete leaf. From treatments I to IV, genera numbers of different foliage characters gradually increased, but their proportion did not followed this trend, indicating that plant diversity was rising along restoration gradient. For instance, genera numbers for simple leaf plant were 8, 11, 25, and 47 for treatment I, II,

III and IV, respectively, accounting for 72.73%, 68.75%, 58.14%, and 69.12% of total genera respectively (Table 6).

Conclusions

There were 86 plant species belonging to 78 genera and 43 families in the degraded purple soil ecosystem. Of the 15 distribution area types in spermatophyte genus, 12 types appeared in the purple soil ecosystem, and tropic types accounted for 55.07%, which indicated that geographical composition were characterized by tropical flora. In the plantation ecosystem, community physiognomy of understory was dominated by microphanerophyte evergreen shrub that has small-sized, grassy, entire costa, and simple-shape leaves. Along restoration gradient, floristic composition became more complex. Additionally, spermatophyte genera for each distribution area type increased, and plant growth type and life form spectra also enriched. From treatments I to IV, genera numbers of different foliage characteristics gradually increased, but their proportion did not follow this trend. In conclusion, the plantation ecosystem on purple soil became more stable, and its flora and physiognomy were gradually complex and diverse along restoration gradient.

Acknowledgement

We thank Prof. Jiang Fengqi and Prof. Zeng Dehui for their valuable comments on the manuscript.

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